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STUDIES OF THE SURVIVAL TIME OF BACTERIA ON SURFACES AND THE POSSIBILITIES OF INFLUENCING IT

III. INFLUENCE OF VARIOUS LIGHTING CONDITIONS AND PREVIOUS DISINFECTION IN THE USE OF PLASTICS

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STUDIES OF THE SURVIVAL TIME OF BACTERIA ON SURFACES AND THE POSSIBILITIES OF INFLUENCING IT

III. INFLUENCE OF VARIOUS LIGHTING CONDITIONS AND PREVIOUS DISINFECTION IN THE USE OF PLASTICS

K.O. Gundermann and S. Glueck[1]

ABSTRACT. The examination of the survival time of bacteria on plastics revealed an unequivocal, inherent bactericidal effect of some materials (alkyd varnish, phenolic resin) as well as an at least unfavorable effect on the germs of some others (PVC, polyacetal) when all test conditions (daylight, UV irradiation) were taken into consideration. In this context, additives apparently also play a role apart from the basic chemical structure. The strong influence of the daylight on the lifetime could be confirmed again. The late effect of disinfectants is in part dependent on the surface material. The phenolic agent, for instance, showed a considerable late effect on polyethylene, polystyrene, polypropylene, polycarbonate, phenolic resin, and acrylic glass; the delayed effect of this agent was reduced in the case of PVC and polyacetal.

Following our brief report on the survival time of bacteria on conventional materials and on dyes [2,3], we have prepared the present paper to give the results of the experiments with plastics which were performed at the same time. Since the utilization of plastics in hospitals is steadily increasing, both structural materials and utensils made of plastic are playing an increasingly important role, so that it appeared advisable to include such materials in our tests. This is all the more desirable in view of the fact that there are apparently hardly any studies dealing with this problem. Experiments conducted by Knorr and Graef on the problem of the hygienic evaluation of plastic dishes have shown that the investigated finished products made of Melamine still gave off small quantities of formaldehyde even after /480*

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*Numbers in margin indicate pagination in the foreign text.

they had been used for a long time. However, a germicidal affect was observed only at moist places. It was also reported that certain types of germs, under certain conditions, can lead to amicrobial corrosion of plastics; Schwartz [9,10], for example, has dealt with this problem in highly comprehensive tests and although softeners and other additives are primarily broken down, this problem was secondary in terms of our project, inasmuch as an adaptation of bacteria to the plastics in the relatively short time during which the germs live on exposed surfaces cannot be expected.

Hence, the question of an intrinsic batericidal property of the material as well as the problem of which survival chances are given to the bacteria by the physical surface structure was more important for our studies. For this reason, by analogy with the experiments with conventional materials, the bacteria that occur on individual material surfaces were exposed to various light conditions and UV irradiation. In addition, in order to examine the question of whether disinfectants are absorbed on the surfaces and thereby remain relatively effective for a long period of time, orientation experiments were carried out with phenolic, formalin-containing and surface-active substances. We were primarily interested in the aftereffects of the substance, so that the innoculation with the germs was always carried out only after disinfection. /481

MATERIALS AND METHODS.

The following materials were used in the studies:

1. Plastic materials made of PVC:
   a. PVC, soft (rough plate),
   b. PVC, hard (rough plate),
   c. Tile, PVC, soft,
   d. Floor covering, PVC, soft,
   e. Drapery, PVC, soft,
   f. Synthetic leather, PVC,
   g. Synthetic leather, PVC, soft,
   h. Film, PVC, soft,
2. Plastic materials made of polyethylene:
   a. Low-pressure polyethylene plus stabilizer (rough plate),

b. High pressure polyethylene (without additives, rough plate),
c. Dishes made of polyethylene,
d. Low-pressure polyethylene (formaldehyde resistant, rough plate),
e. Polyethylene (rough plate),
f. Urine bottle, high-pressure polyethylene.

3. Polystyrene plastics (including mixtures):
   a. Breakage resistant polystyrene (stamped plate),
   b. Breakage resistant polystyrene (+ lubricant + stabilizer, extruded plate),
   c. Mixed polymerisate of styrene + acrylnitrile + lubricant (rough plate),
   d. Polystyrene (rough plate),
   e. Dishes, mixed polymerisate.

4. Plastic material made of cellulose acetate:
   a. Cellulose acetate + softener on phthalic acid base (rough plate),
   b. Cellulose acetate + highly flame-resistant softener (rough plate).

5. Various polymerisates:
   a. Polyacetal (not phenol-resistant, rough plate),
   b. Polypropylene (rough plate),
   c. Thermal plastic polycarbonate (rough plate).

6. Plastic materials made of Melamine resin:
   a. Melamine resin surface (finished product),
   b. Melamine resin surface (finished product).

7. Other plastics:
   a. Alkyd paint, synthetic resin paint on tung oil base (linseed oil-tung-oil-alkyd),
   b. Phenol resin (rough plate),
   c. Acrylic plastic (rough plate).

In accordance with the method described in the first part, suspensions of *S. aureus*, *S. albus*, *E. coli* and *Klebsiella* were placed on the plastic plates and dried, after which the plates were investigated under the following conditions:

1. Application of a suspension of germs in water, storage of the plates in darkness; 2. application of a suspension of germs in water, storage of the plates in daylight; 3. application of a suspension of germs in bouillon, storage of the plates in daylight; 4. application of a germ suspension in water, storage of the plates with exposure to UV radiation; 5. application of a germ suspension in bouillon, storage of the plates with UV radiation.

The daylight quotient was once again 0.2 to 2%, the UV intensity under experimental conditions 4 and 5 was 2.4 $\mu W/cm^2$, and the daily dose was 0.2 Ws/cm^2. The number of germs was determined after 1, 3, 5 and 7 days by means of smears.

In the disinfection tests, germ application was carried 1, 6, and 12 hours after disinfection. The first version of the experiment was carried out both with an aqueous and a bouillon suspension. The other two were carried only with aqueous germ suspensions. Smears were taken after 12, 24 and 36 hours.

RESULTS

Table 1 shows a summary of the average germ counts for each batch. These values were once again obtained as follows: the smear values for each day were added up for each material and the average from the experiments with the four germ types was calculated from these summed germ counts. Since all of the experiments were performed twice, the values were based on each test.

Table 2 shows how great the percentile deviation of these values from the average of each experimental condition was.

As far as was possible, the plastics were arranged in groups in accordance with their composition. The dark values, which could provide information about an intrinsic bactericidal action, however, showed no agreement within these groups. Even among the others, the basic substance apparently played a lesser role as far as survival of germs was concerned than the balance of the chemical composition or the surface structure. For example, in the group of plastics made of PVC, from (the two types of synthetic leather and the drapery material) displayed a largely similar behavior of germ counts under all experimental conditions, while for other substances (soft PVC [rough plate]

and tiles made of soft PVC) were such that under UV light the germ counts decreased more slowly (or in the case of hard PVC [rough plate] more rapidly). /482
On certain plastics (alkyd paint, polyethylene) the germs applied in the bouillon survived for relatively longer periods of time while their survival time on acrylic plastic was evidently shorter.

Table 1. Effect of Daylight and UV Radiation on Bacteria on Plastics*

Composition	D/W**	H/W	H/B	UV/W	UV/B
1. a Polyvinylchloride***	1120	615	1919	197	1460
b Polyvinylchloride	1487	660	2009	87	408
c Polyvinylchloride	1443	989	2124	306	1492
d Polyvinylchloride	1515	680	1581	51	692
e Polyvinylchloride	1023	498	1186	21	475
f Polyvinylchloride	1010	390	1369	69	371
g Polyvinylchloride	986	574	1802	6	303
h Polyvinylchloride	1614	405	2173	125	1628
2. a Polyethylene	1746	805	----	---	----
b Polyethylene	1450	853	----	---	----
c Polyethylene	2002	834	3587	32	1210
d Polyethylene	1790	849	2634	154	1140
e Polyethylene	1271	682	2565	120	1090
f Polyethylene	1420	890	2238	98	400
3. a Polystyrene	1299	841	----	---	----
b Polystyrene	1430	540	----	---	----
c Polystyrene	1606	575	----	---	----
d Polystyrene	1182	795	2003	95	1225
e Polystyrene	804	735	2293	98	1121
4. a Cellulose Acetate	1154	540	----	---	----
b Cellulose Acetate	1268	517	----	---	----
5. a Polyacetal	1208	571	1378	31	770
b Polypropylene	1910	794	2572	283	1017
c Polycarbonate	1496	812	2455	242	1169
6. a Melamine Resin	1226	786	2042	185	892
b Melamine Resin	1340	877	2765	158	1058
7. a Alkyd Paint	310	145	1541	31	463
b Phenol Resin	627	380	1929	157	725
c Acrylic Plastic	1448	1230	1859	268	690
Average	1340	700	2040	147	873
Control: Glass	2312	1145	4400	174	1724

* Application of various germ suspensions and determination of germ density smears after 1, 3, 5 and 7 days. Summation of the germ values obtained in this fashion for each experiment. Data given here is the average of eight tests.

** D/W = Application of germs in water, storage in darkness, H/W = application of germs in water, storage in daylight, H/B = application of germs in bouillon, storage in daylight, UV/W = application of germs in water, storage in UV light, UV/B = application of germs in bouillon, storage in UV light.

*** For details, see the section "Materials and Methods."

Generally favorable results were obtained with alkyd paint, a number of plastics made of PVC, and phenol resins. It is also striking that all of the plastics display significantly lower values than the glass standard, i.e., all plastics have a certain bactericidal effect.

The investigation of the survival time of bacteria on various plastics following preliminary application of a disinfectant in some cases apparently indicated a relationship between the survival time of the bacteria, the type of plastic and the type of agent (Table 3). /483

Table 2. Effect of Daylight and UV Radiation on Bacteria on Plastics.*

Composition	D/W	H/W	H/B	UV/W	UV/B	Average Percentile Deviation
1. a Polyvinylchloride	84	88	94	134	167	113
b Polyvinylchloride	111	94	98	59	47	82
c. Polyvinylchloride	108	128	104	208	171	144
d Polyvinylchloride	113	97	78	27	79	79
e Polyvinylchloride	76	71	58	14	54	55
f Polyvinylchloride	75	56	67	47	43	57
g Polyvinylchloride	79	82	88	4	35	58
h Polyvinylchloride	120	58	107	85	186	111
2. a Polyethylene	130	115	---	---	---	(122)
b Polyethylene	108	122	---	---	---	(115)
c Polyethylene	149	114	176	22	139	120
d Polyethylene	134	121	115	105	131	121
e Polyethylene	95	97	126	82	125	105
f Polyethylene	106	127	110	67	46	91

(Continued on next page)

Table 2. (Continued)

Composition	D/W	H/W	H/B	UV/W	UV/B	Average Percentile Deviation
3. a Polystyrene	97	120	---	---	---	(109)
b Polystyrene	107	79	---	---	---	(93)
c Polystyrene	120	82	---	---	---	(101)
d Polystyrene	88	114	98	65	140	101
e Polystyrene	60	105	113	67	129	95
4. a Cellulose Acetate	86	77	---	---	---	(82)
b Cellulose Acetate	95	74	---	---	---	(85)
5. a Polyacetal	90	82	68	48	88	75
b Polypropylene	142	113	126	193	116	138
c Polycarbonate	112	116	120	164	134	129
6. a Melamine Resin	92	112	100	126	102	106
b Melamine Resin	100	125	136	108	121	118
7. a Aklyd Paint	23	21	76	21	53	39
b Phenol Resin	47	54	94	107	83	77
c Acrylic Plastic	108	176	91	182	79	127
Average 100 =	1340	700	2040	147	873	
Control: Glass (Relative)	173	164	216	118	197	174

* See Table 1, data here expressed as percentage of average for each column.

While in the formalin-containing and surface-active preparations there was a dependence of the late effect on the type of plastic only in individual cases (e.g., in phenol resin), in the case of the phenolic materials it became evident that the reduction of the number of germs was considerably intensified on plates made of polyethylene and on various polystyrenes, and particularly on polycarbonate, phenol resin and acrylic plastic. In general, the late effect of the disinfectant remains for a long period of time.

As we can see from Table 4, 24 hours after application of the bacteria it was scarcely possible to find any germs, regardless of whether the disinfectant was applied 1 or 12 hours prior to the application of the bacteria. It was only in the case of the surface-active preparation that a somewhat less satisfactory picture was found.

Table 3. Late Effect of Certain Disinfectants on Specific Plastics.* /484

Composition	Formalin-Containing Preparation, 1.5%	Phenolic Preparation, 3%	Surface-Active Preparation, 2%
1. a Polyvinylchloride	82	67	144
b Polyvinylchloride	123	127	104
c Polyvinylchloride	129	205	102
d Polyvinylchloride	123	209	120
e Polyvinylchloride	114	174	111
f Polyvinylchloride	105	192	125
g Polyvinylchloride	101	157	115
h Polyvinylchloride	121	162	129
2. a Polyethylene	113	41	82
b Polyethylene	123	79	108
c Polyethylene	---	---	---
d Polyethylene	121	80	85
e Polyethylene	94	16	82
f Polyethylene	125	77	83
3. a Polystyrene	76	49	102
b Polystyrene	85	40	104
c Polystyrene	104	64	109
d Polystyrene	94	47	92
e Polystyrene	---	---	---
4. a Cellulose Acetate	94	102	96
b Cellulose Acetate	104	139	101
5. a Polyacetal	103	200	82
b Polypropylene	112	61	85
c Polycarbonate	80	16	115
6. a Melamine Resin	103	109	81
b Melamine Resin	---	---	---
7. a Alkyd Paint	101	141	106
b Phenol Resin	45	16	76
c Acrylic Plastic	81	11	91
Average	100 = 962	528	1472
Control: Glass (Relative)	181	166	145

* Application of germs 1 to 12 hours after disinfection of the surfaces, smears taken after 1, 12, 24 and 48 hours. Combination of the germ count (added as in Table 1) for all experimental versions, i.e., numbers based on 32 tests. Data here expressed as percentage of averages for each column.

Table 4. Average Germ Count on 27 Plastics Following Preliminary Application of Disinfectant.*

Preparation	Germ Count After __ Hours	Application of Disinfectant 1 Hour	6 Hours	12 Hours Prior to Application of Bacteria
1. Formalin-Containing Preparation	12	56	126	212
	24	0.6	9	19
2. Phenolic Preparation	12	23	53	115
	24	0.2	7	10
3. Surface-Active Preparation	12	175	268	501
	24	26	88	227
Control	24	539	539	539

*Data given as average of the added germ counts from 216 tests (see Table 1).

DISCUSSION

Utilization of plastics in hospitals is undoubtedly increasing and the question of the interaction between plastics and microorganisms is an extremely timely one. The diversity of plastics makes it seem nearly impossible to gain any kind of general idea as far as their applicability from the hygienic standpoint is concerned. In particular, aside from the large number of basic substances that have come into use, there are many plastics on the market which contain small amounts of additives. They either remain as residue from the manufacturing process or are added to change certain characteristics such as plasticity, color, etc. Since the behavior with respect to microorganisms is affected by them, it is practically impossible to obtain generally valid or transferrable results by studying a few prototypes. Schwartz [9, 10], who studied the question of microbial corrosion in comprehensive tests for many years, has demonstrated this very clearly. In the case of plastics whose chemical composition is not completely known (certain chemical components, as a rule, remain trade secrets held by the manufacturer), the investigative results that have been obtained can serve only as guidelines, as a rule.

In our studies, it became very clear that a uniform behavior was only partially to be found within the groups of the same basic substances. While in the groups of polyethylenes and the group of polystyrene products we did obtain some similar results under diverse conditions, there were marked deviations in the case of plastics with a PVC base. Evidently additives were /485 contained in the products that were used as synthetic leather or drapery material which change the behavior. This is also the reason why Pantel [8] found no bactericidal action in PVC. The product which he studied was probably modified in its behavior with respect to bacteria by similar additives, so that comparison with the studies of Kabelik [4] of the data of Tarasov [11] do not seem to make much sense. Hence, it should merely be pointed that some of the investigated products in the PVC plastic group, the polyacetals and phenolic resins and especially the alkyd paints exhibit stronger bactericidal properties than the other materials. In addition, the bouillon leads to a more pronounced protective effect in certain materials (alkyd paint, some of the polyethylenes and one of the melamine resins).

In the disinfection tests, a definite dependence of the aftereffects upon the surface material was observed in connection with phenolic preparation. While the formalin-containing preparation remained effective for a longer period of time only on the phenolic resin, so that it was probably the intrinsic bactericidal nature of this substance that was responsible, the surface active substance on the PVC material showed a more than average duration in several instances.

It is impossible to describe at the present time whether the marked late effect of the phenolic substance on a large number of plastics (polyethylene, polystyrene, polypropylene, polycarbonate, phenolic resin, acrylic plastic) was caused by absorption and later liberation of the phenols or only the effect was not influenced at least in some cases. We know in the case of rubber for example, that absorption of phenolic agents does occur (Buech et al., [1]), but may also play a role in the case of plastics. Kingston and Noble [5] hold that only substances which absorb the disinfectant can be effective antibacterially for a long period of time. Harmful effects caused by absorption of phenol in rubber tubing used for intubation, as described by Buech et al. [1], have thus far not be reported for plastics. In the utilization of plastic dishes, which are made from precisely those materials in which the pronounced late effect of the phenolic agent was found, the problem arises that the objects that are used most frequently soon become cracked and difficult to disinfect as a result (Muehlens [7]). The danger that phenols could enter the food that is placed on such materials following their disinfection, because not all of the residue was removed or could be removed, has not been proven. It is also possible that infectious processes could be triggered, for example by bedpans, etc. made of such plastics following previous disinfection with phenolic agents when they come in contact with the patient's skin, which may perhaps be broken.

On the other hand, a reduced aftereffect of the phenolic agent has been found in certain substances (PVC, polyacetal). We still do not know whether this constitutes a true inhibition, caused by chemical inactivation of the phenol, or whether there is really no intensified aftereffect.

Essentially, not only the chemical class of materials but also the content of additives is important as far as utilization in a hospital is concerned. Hence, it must be made general practice to test all products individually with respect to their properties before definite statements can be made regarding recommendation for use in hospitals. The disinfection tests, however, although they are primarily of an orientational character, have presented some very important guidelines for the selection of plastics intended for diverse applications. If the phenolic bodies bind themselves to a surface in some form and remain active, this material is particularly suitable, since a long survival time is impossible for the bacteria. On the other hand, the utilization of these materials or the disinfection of these materials by phenolic agents may be undesirable as the possibility exists that these substances could come directly or indirectly in contact with the human body following disinfection.

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